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ABSTRACT

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Effectiveness of Conceptual Change Text Oriented Instruction on Students' Understanding of Cellular Respiration Concepts

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Abstract

The purpose of the study is to compare the effectiveness of conceptual change text oriented instruction and traditional instruction on students' understanding of cellular respiration concepts and their attitudes toward biology as a school subject. The sample of this study consisted of 84 eleventh grade students from the four classes of a high school. Two of the classes were randomly assigned to control group in which students were instructed by traditionally designed biology instruction and the other two classes were randomly assigned to experimental group in which conceptual change texts oriented instruction was implemented. Analysis of the data indicated that students exposed to conceptual change texts oriented instruction had better understanding of cellular respiration concepts than those exposed to traditional instruction. On the other hand, both experimental and control group students had similar attitudes toward biology as a school subject.

Introduction

In recent years, many of the researchers in science education have focused on students' conceptual development and cognitive processes (Mintzes, Trowbridge, Arnaudin & Wandersee, 1991; Songer, 1993; McComas, 1997; Dekkers & Thijs, 1998; Kwon & Lawson, 2000). They mainly accepted that each student has a different cognitive structure due to their different abilities, backgrounds, attitudes and experiences. According to Piaget (1969), students construct new knowledge on their previous cognitive structures. Therefore, students may generate different meanings from the upcoming information due to their different cognitive structures. Students' views and explanations of science concepts may differ from those generally accepted by the scientists. Alternative views have been given various terms including "children science" (Gilbert, Osborne & Fensham, 1982; Osborne, Bell, & Gilbert, 1983), "alternative frameworks", (Driver & Easly, 1978; Driver & Ericson, 1983), "naive beliefs" (Caramazza, McCloskey & Green, 1981), "preconceptions", (Anderson & Smith, 1987) and "misconceptions" (Cho, Kahle & Nordland, 1985; Griffiths & Preston, 1992).

Misconceptions regarding science concepts have been studied by science educators for many years (Driver, 1981, 1983; Posner, Strike, Hewson & Gertzog,

1982; Anderson & Smith 1987; Hewson & Hewson, 1983; McComas, 1997; Dekkers & Thijs, 1998; Kwon & Lawson, 2000). Studies, specifically, in biology education showed that students have misconceptions about many biological concepts (Hazel & Prosser, 1994; Westbrook & Marek, 1991; Browning & Lehman, 1988; Fisher, 1985; Brumby, 1984; Teixeria, 2000; Arnaudin & Mintzes, 1985; Yip 1998). Some of the studies in biological education have focused on the understanding of cellular respiration (Anderson, Sheldon & Dubay, 1990; Songer & Mintzes, 1994; Simpson & Marek, 1998; Haslam & Treagust, 1987; Seymour & Langden, 1991; Lawson, 1988; Fisher & Lipson, 1986). These studies demonstrated that students have several misconceptions regarding cellular respiration.

Songer and Mintzes' (1994) study conducted with 200 novice and experienced students indicated that students have difficulties in understanding the role of oxygen in cellular respiration. Students believed that O_2 is used in all steps of glucose reduction reactions. One significant misconception of novice students reported in this study was the belief that glucose is the only substrate used in the cellular respiration. Another misconception identified was the notion that CO_2 is used instead of O_2 in fermentation reactions. Students participated in this study were not able to recognize yeast as a living organism and they believed that yeast releases O_2 in the fermentation process. Another prevalent misconception was the idea that plants do not respire (Songer & Mintzes, 1994).

In addition to these, the results of the some studies concerning students' misconceptions about cellular respiration showed that students have conceptual difficulties in understanding the function of respiration. Students defined respiration as inhaling O_2 and exhaling CO_2 (Songer & Mintzes, 1994; Anderson, Sheldon, Dubay, 1990). Sanders (1993) identified same misconception in biology teachers.

Moreover, some teachers believed that respiration of plants occurs only at night. Many teachers responded that photosynthesis is the process that makes energy available for metabolism in plant. Another misconception identified in Sanders' (1993) study was that oxygen is essential for all organisms.

Yuruk and Cakır (2000) identified several misconceptions concerning cellular respiration. Some of the common misconceptions documented in this study were: heat produced during respiration reactions is used in cellular activities; glucose is a product of cellular respiration reactions; CO_2 is produced at the end of both lactic acid and alcoholic fermentation reactions; yeast makes photosynthesis instead of respiration under light; all the energy released during cellular respiration reactions is stored; glycolysis in fermentation reactions requires more energy than that in aerobic respiration reactions. The other misconceptions identified in this study were the notions that only aerobic respiration occurs in muscle cells and water is produced as a result of fermentation reactions.

Since new knowledge is constructed on the base of existing cognitive structure, misconceptions have to be dispelled in order to prevent new ones developing. However, students' misconceptions may be so resistant to change that traditional instruction may be inadequate to change those with scientific concepts (Anderson & Smith, 1987; Champagne, Gunstone & Klopfer, 1985; Driver & Easly, 1978; Fredette & Lochead, 1980; Osborne, 1983; Wandersee et al, 1994). Recent studies in science education have showed that teaching strategies based on conceptual change approach have been effective at dispelling students' misconceptions. Posner et al. (1982) postulated four conditions that are necessary for conceptual change to occur: (a) there must be dissatisfaction with the existing conception (that is, prior concept must be inadequate to solve existing problem), (b) the new conception must

be intelligible (that is, conception must be understandable), (c) the new conception must appear initially plausible (that is, it must be useful in solving the problems), (d) the new conception must be fruitful (that is, it must be useful in solving future problems).

One of the successful techniques based on conceptual change approach is the use of conceptual change texts which refute commonly held naive concepts (Dole & Niedehauser, 1990; Hynd & Alverman, 1986; Maria & MacGinitie, 1987; Chambers & Andre, 1997; Guzetti, Synder, Glass, & Gamas, 1993). The aim of using conceptual change text is to activate learners' preconceptions and warn learners about possible misconceptions about the topic of interest. In conceptual change texts misconceptions are contrasted with the scientifically accepted conceptions by providing examples and explanations. In these texts learners are asked explicitly to make prediction about a given situation before presenting the misconceptions and explanations about the given situation and they are recommended to change their misconceptions with scientifically accepted ones (Chambers & Andre, 1997).

Cellular respiration has a central role in understanding of several conceptual change schemes including energy flow in ecosystem and metabolic activities of organisms such as digestion, circulation, respiration and excretion. In order to understand these concepts meaningfully, and to prevent the development of new scientifically unacceptable conceptions, misconceptions about cellular respiration should be remedied. The purpose of this study is to compare the effectiveness of conceptual change texts oriented instruction and traditionally designed instruction on students' understanding of cellular respiration and their attitudes toward biology as a school subject.

Method

Subjects

Participants in this study were 84 eleventh grade students from the four classes of the same teacher in a high school. Two classrooms of experimental group with 40 students were randomly assigned to conceptual change texts oriented instruction (CCTI) while traditionally designed biology instruction (TBI) was assigned to the other two classes with 44 students.

Research Design

Pre-test post-test experimental design was used as a research design. Students in control group were taught by traditionally designed instruction while students in experimental group were exposed to conceptual change text oriented instruction. Cellular respiration concept test was administered as pre-test in order to control previous learning and existing conceptions in cellular respiration. Same test was administered as post-test to determine students' understanding of cellular respiration concepts. In addition to that, attitude scale was implemented in both experimental and control groups after the instruction

Instrumentation and Materials

Cellular Respiration Concepts Test (CRCT)

In order to assess students' understanding of cellular respiration concepts a 23 item multiple choice concept test was developed by the researchers. During the development of Cellular Respiration Concepts Test (CRCT), firstly, instructional objectives of the unit "Cellular Respiration" were stated. Secondly, students' typical conceptual difficulties, and misconceptions were identified from

previous studies in literature and from the informal interviews with 3 biology teachers who have more than 5 years of experience in teaching biology. The misconceptions identified through literature review and those identified as a result of informal interviews with the teachers are presented in Table 1. Finally, items of the test were constructed according to the instructional objectives and identified misconceptions about cellular respiration concepts. Each item of the test had one correct answer and three distracters which reflected students' misconceptions related to cellular respiration. One of the items in CRCT is shown in Figure 1. In distracter A of this item, it was aimed to examine students' understanding of energy production at the end of respiration reactions. Students who have this misconception may think that energy produced in one cell may be used by other cells. The students who hold the misconception that heat produced during the respiration reaction may be used in cellular activities may select the distracter B. If they are unable to identify the difference between eukaryote and prokaryote organism's energy production in respiration reactions, they may choose distracter C. Some students may also not understand that the same amount of energy produced in glycolysis reaction occurs in both aerobic and anaerobic respiration reactions. Therefore, they may be unable to find answer D.

A group of experts in measurement and evaluation, biology, and biology education examined this test for representativeness and appropriateness of the test items. The pilot study of the test was implemented to 193 eight and ninth grade students in a high school. The reliability of the test was found to be .80. Final form of the test was administered as a pre-test and post-test to both control and experimental groups.

Attitude Scale Toward Biology As A School Subject (ATB)

In order to measure students' attitudes toward biology as school subject the scale developed by Geban et al. (1994) was used. Geban et al. (1994) developed an attitude scale toward chemistry. This scale was adapted so that it measures students' attitudes toward biology as a school subject. The scale contains 15 Likert type items regarding enjoyment and importance of biology course. The reliability of the scale was found to be 0.89.

Conceptual Change Texts

The conceptual change texts (CCT) used in this study was designed to help students change their preconceptions or misconceptions with the scientific ones. Conceptual change texts were developed incorporating the four conditions of conceptual change approach (Posner et al., 1982). Firstly, students were asked a question about a given situation in order to activate their prior knowledge. Then, students were informed about common misconceptions regarding the topic. Next, scientific explanations and examples were provided about the topic to refute the common misconceptions. It was emphasized that the misconceptions fail to explain the real phenomena. Finally, students were asked further questions in order to stimulate them to apply the new concept to answer the question. An example to the conceptual change texts can be seen in Figure 2.

Procedure

This study took place over four weeks. Before the treatment, the teacher was trained about the data collection procedure and implementation of CCT. After training the teacher, cellular respiration concept test was administered in both experimental

and control groups as pre-test. One week after the administration of pre-test instruction concerning cellular respiration was started in both groups. In the traditionally designed biology instruction, the teacher provided instruction through lecture and discussion. Meanwhile, experimental group was instructed by using conceptual change texts. The teacher, firstly, explained the concepts though lecturing and, then, used conceptual change texts to supplement his instruction.

During the implementation of CCT, students were asked to read the CCT before coming to school. In the classroom the teacher posed the questions in the text to activate students' preconceptions. Students were directed to answer the questions by themselves. Then, the scientific explanation of the concept was read from CCT by emphasizing that common misconceptions do not explain the real phenomena. Students were asked to discuss whether their responses to questions were scientifically acceptable or not. Finally, students were advised to replace their existing concepts with the scientific ones. One week after the treatment, CRCT and ATB were administered to both experimental and control groups as post tests.

Results

In order to compare the effectiveness of conceptual change texts oriented instruction (CCTI) and traditionally designed biology instruction (TBI) with respect to students' understanding of cellular respiration concepts and their attitudes toward biology as a school subject Multivariate Analysis of Covariance (MANCOVA) was used. The dependent variables were students' attitudes toward biology (ATB) and their cellular respiration concept achievement (CRCA) measured by post-CRCT scores. The independent variables were treatment called as group and students' pre-cellular respiration concept achievement (pre-CRCA) measured by pre-CRCT scores.

In order to statistically equalize differences between experimental and control groups, students' pre-cellular respiration concept achievement was determined as a potential covariate in the MANCOVA. The covariate, pre-CRCA, was entered before the group into the model so that the variance caused by pre-achievement can be removed from the variance caused by group on the dependent variables. Table 2 summarizes the result of the multivariate tests of MANCOVA.

As table 2 indicates, group resulted in significant multivariate F. This means that there was found a significant mean difference between students taught with conceptual change oriented instruction and those exposed to TBI with respect to the collective dependent variables of students' understanding of cellular respiration concepts and their attitudes toward biology as a school subject.

In order to decide which dependent variable was responsible for the significance the results of follow-up ANCOVAs are examined. Table 3 presents the results of follow-up ANCOVAs. Table 3 shows that the group resulted in a significant univariate F for post-cellular respiration achievement although it did not result in significant univariate F for attitude toward biology. That is there was a significant mean difference between experimental and control group students in terms of their cellular respiration concepts understanding. However, the results indicate that there was no significant difference between experimental and control groups in terms of their attitudes toward biology. The direction of the effect of the treatment can be examined through the adjusted means for each dependent variable among groups. Table 4 demonstrates the adjusted means for the dependent variables across groups. As table 4 indicates, experimental group has higher adjusted mean value of post-cellular respiration achievement.

Discussion and Implication

The main aim of the study was to compare the effectiveness of conceptual change text oriented instruction and traditionally designed biology instruction with respect to students understanding of cellular respiration concepts and their attitudes toward biology as a school subject. The results show that there is a significant difference between CCTI and TBI with respect to students' understanding cellular respiration. Students who were exposed to CCT had better understanding of cellular respiration concepts than those who were taught by traditional instruction. This finding of the study is supported by the previous studies (Wang & Andre, 1991; Guzzetti et al., 1993, Hynd et al., 1994). The difference in understanding cellular respiration concept between students exposed to CCTI and those exposed to TBI can be attributed to the nature of conceptual change texts.

In this study conceptual change text oriented instruction helped students have better understanding of cellular respiration concepts by activating their misconceptions, producing dissatisfaction and providing correct explanation which is both understandable and plausible. Moreover, text-based materials encouraged intensive student-student, student- teacher interaction during discussion section to understand concepts accurately. On the other hand, during the TBI students' preconceptions and misconceptions were ignored during instruction. Thus, students in TBI group acquired scientific conceptions with the continued presence of the alternative conception in their conceptual framework..

Although CCTI had significant effects on students' understanding of cellular respiration concepts, it did not make a significant difference in students' ATB as a school subject. Both groups showed statistically the similar attitudes toward biology. Textual information is one of the primary learning activities in school settings. Use of

text-based information is not a significant change for the students. Therefore, these texts may have not created difference in students' ATB as a school subject. At least the result of this study show that conceptual change texts did not produce negative attitudes toward biology.

Previous studies have shown that students have various misconceptions about several science topics. If these misconceptions are ignored during instruction, new misconceptions can be developed in students' minds which may hinder meaningful understanding of science concepts. This study shows that conceptual change texts can be used as an effective tool to prevent or change students' misconceptions. Therefore, teachers should be informed about conceptual change text oriented instruction in order to promote conceptual change in students' cognitive structures. Moreover, conceptual change texts can be incorporated into textbooks. Through the use of conceptual change texts money and effort can be saved compared to the other learning activities in which extra instructional materials are used.

References

Anderson, C.W., Sheldon, T. H., & Dubay, J. (1990). The effects of instruction on college nonmajors conceptions of respiration and photosynthesis. *Journal of Research in Science Teaching, 27* (8), 761-776.

Anderson, C. W., & Smith, E. L. (1987). Teaching science. In V. Richardson-Koehler (Ed.), *Educator's handbook: A research prospective* (pp.84-111). New York: Longman.

Arnaudin, M. W., & Mintzes, J. J. (1985). Students' alternative conceptions of the human circulatory system: A cross age study. *Science Education, 69*(5), 721-733.

Browning, M.E., & Lehman, J. D. (1988). Identification of student misconceptions in genetics problem solving via computer program. *Journal of Research in Science Teaching 25*(9), 747-761.

Brumby, M.N. (1984). Misconceptions about the concept of natural selection by medical biology students. *Science Education ,68*(4) 493-503.

Yuruk, N., & Cakir, O. S. (2000). Lise ogrencilerinde oksijenli ve oksijensiz solunum konusunda gorulen kavram yanılgılarının teshisi. [Diagnosing high school students' misconceptions about aerobic and anaerobic respiration] *Hacettepe Universitesi Egitim Fakultesi Dergisi. 18*, 185-191.

Caramazza, A., McCloskey, J., & Green, B. (1981). Naive beliefs in sophisticated subjects: Misconceptions about trajectories of objects. *Cognition*, 9, 111-123.

Chambers, K. S., & Andre, T. (1997). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current. *Journal of Research in Science Teaching, 34*, 107-123.

Champagne, A., Gunstone, R., & Klopfer, L. (1985). Effecting changes in cognitive structures among physical students. In L. West and L. Pines (Eds.), *Cognitive Structure and Conceptual Change*. London: Academic Press.

Cho, H., Kahle, J. B., & Nordland, F. H. (1985). An investigation of high school textbooks as source of misconceptions and difficulties in genetics and some suggestions for teaching genetics. *Science Education, 69*, 707-719.

Dekkers, P.J.J.M. & Thijs, G.D. (1998). Making productive use of students' initial conceptions in developing the concept of force. *Journal of Research in Science Teaching*, 31-50.

Dole, J. A., & Niederhauser, D. S. (1990). Student's level of commitment to their naive conceptions and their conceptual change learning from texts. In J. Zutell and McCormick (Eds.), *Literacy theory and research: Analyses from multiple paradigms.* Chicago: National Reading Conference.

Driver, R., & Easly, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education, 5*, 61-84.

Driver, R. (1981). Pupils' alternative frameworks in science. *European Journal of Science Education, 3*(1), 93-101.

Driver, R. (1983). *The pupil as scientist.* Milton Keynes, England: The Open University Press.

Driver, R. & Erickson, G. (1983). Theories in action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science. *Studies in Science Education, 10*, 37-60.

Fisher, K. M. (1985). A misconception in biology: Amino acids and translation. *Journal of Research in Science Teaching, 22*(1), 53-62.

Fisher, K. M. & Lipson, J. I. (1986). Twenty misconceptions about students' errors *Journal of Research in Science Teaching, 23* (9), 783-803.

Fredette, N.H., & Lockhead, J.(1980). Student conceptions of simple circuits. *The Physics Teacher, 18* (3), 194-198

Geban, Ö., Ertepınar, H., Yılmaz, G., Altın, A., & Şahbaz, F. (1994). Bilgisayar destekli eğitimin öğrencilerin fen başarılarına ve fen bilgisi ilgilerine etkisi [The effect of computer adapted instruction of students' science achivement and on their attitudes toward science]. *I. Ulusal Fen Bilimleri Eğitimi Sempozyumu Bildiri Özetleri Kitabı* (pp.1-2). 9 Eylül University, İzmir.

Gilbert, J. K., Osborne, R. J., & Fensham, P. J. (1982). Children's science and its consequences for teaching. *Science Education, 66*, 623-633.

Griffiths, A. K., & Preston, K. R. (1992). Grade-12 students' misconceptions relating to fundamental characteristics of atoms and molecules. *Journal of Research in Science Teaching, 29*, 611-628.

Guzzetti, B. J., Snyder, T. E., Glass, G.V., and Gamas, W. S. (1993). Meta analysis of instructional interventions from reading education and science education to overcome misconceptions. *Reading Research Quarterly, 28*, 116-159.

Haslam, F., & Treagust, D. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of Biological Education, 21*, 203-211.

Hazel, E. & Prosser, M. (1994). First-year university students' understanding of photosynthesis, their study strategies and learning context. *American Biology Taecher, 56*(5), 274-279.

Hewson, G. M., & Hewson, W. P. (1983). Effect of instruction using students' prior knowledge and conceptual change strategies on science learning. *Journal of Research in Science Teaching, 20*, 731-743.

Hynd, C., & Alverman, D.E. (1986). The role of refutation text in overcoming difficulty with science concepts. *Journal of Reading, 29*, 440-446.

Hynd, C.R., McWhorter, J.Y., Phares, U.L., & Suttless, C.W. (1994). The role of instructional variables in conceptual change in high school physics topics. *Journal of Research in Science Teaching, 31* (9), 933-946.

Kwon, Y., & Lawson, A.E. (2000). Linking brain growth with the development of scientific reasoning ability and conceptual change during adolescence. *Journal of Research in Science Teaching, 37* (1), 44-62.

Lawson, A.E. (1988) The acquisition of biological knowledge during childhood: Cognitive conflict or Tabula Rasa. *Journal of Research in Science Teaching. 25*(3), 185-199.

Maria, K., & MacGinitie, W. (1987). Learning from texts that refute the reader's prior knowledge. *Reading Research and Instruction, 26*, 222-238.

McComas, W.F. (1997). The discovery and nature of evolution by natural selection: Misconceptions and lessons from the history of science. *The American Biology Teacher, 59*(8), 492-500.

Mintzes, J.J. (1984). Naïve theories in biology: children's concepts of the human body. *School Science and Mathematics. 84*(7), 548-555.

Mintzes, J., Trowbridge, J., Arnaudin, M., & Wandersee, J. (1991). Children's biology: Studies on conceptual development in the life sciences. In S. Glynn, R. Yeany, & B. Britton (Eds.), *The psychology of learning science* (pp. 179-202). Hillsdale, N.J.: Erlbaum.

Osborne, R.J., (1983). Towards modifying children's ideas about electric current. *Research in Science and Technological Education, 1*, 73-82.

Osborne, R. J., Bell, B. F., & Gilbert, Y. K. (1983). Science teaching and children's view of the world. *European Journal of Science Education, 5*, 1-14.

Piaget, J. (1969). *The child's conception of the world.* Totowo, NJ: Littlefield. Adams, & Co.

Posner, G.J., Strike, K.A., Hewson, P.W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*, 211-227.

Sanders, M. (1993) Erroneous ideas about respiration: The teacher factor. *Journal of Research in Science Teaching, 30(8), 919-934.*

Seymour, J., & Longden, B. (1991). Respiration-That's breathing isn't it? *Journal of Biological Education, 25*, 177-183.

Simpson, W.D., & Marek, E.A. (1988). Understandings and misconceptions of biology concepts held by students attending small high schools and students attending large high schools. *Journal of Research in Science Teaching, 25*, 361-374.

Songer, C. (1993). *Understanding cellular respiration.* Unpublished master's thesis, University of North Carolina at Wilmington, Wilmington, NC.

Songer, C.J.& Mintzes, J.J (1994). Understanding cellular respiration and analysis of conceptual change in college biology. *Journal of Research in Science Teaching. 31* (6), 621-637.

Teixeira, F. (2000). What happens to the food we eat? Children's conceptions of the structure and function of the digestive system. *International Journal of Science Education. 22*(5), 507-520.

Wandersee, J., Mintzes, J., & Novak, J.D. (1994). Research on alternative conceptions in science. In D. Gabel (Ed.) *Handbook of research on science teaching and learning* (pp. 177-210). New York: Macmillan.

Wang, T. & Andre, T. (1991). Conceptual change text and application questions versus no questions in learning about electricity. *Contemporary Educational Psychology, 16*, 103-116.

Westbrook, S. L., & Marek, E. A. (1991). A cross-age study of student understanding of the concept of diffusion. *Journal of Research in Science Teaching. 28*(8), 649-660.

Table 1

Students' Misconceptions Concerning Cellular Respiration.

1. Plants do not respire.
2. Plants respire only at night.
3. O_2 is directly used during glucose reduction reactions.
4. O_2 is used during anaerobic respiration reactions.
5. While animals produce CO_2, plants produce O_2 at the end of respiration
6. All living things use O_2 during respiration reaction.
7. During anaerobic respiration reaction CO_2 is used instead of O_2
8. Inhaling oxygen and exhaling CO_2 is called respiration.
9. CO_2 is produced during both aerobic and anaerobic respiration reactions.
10. CO_2 is produced during both lactic acid and alcoholic fermentation reactions.
11. Energy is produced at the end of photosynthesis reactions
12. Energy produced in one cell is used in other cellular activities.
13. Heat produced during respiration is used in cellular activities.
14. Glucose is produced as a result of respiration.
15. Glucose is used in all respiration reaction.
16. Only yeast makes anaerobic respiration reactions.
17. Yeast makes photosynthesis under light.
18. During glycolysis in fermentation reaction more O_2 is required as compared to aerobic respiration reaction.
19. All energy produced during respiration is stored.
20. Same amount of ATP is produced for both eukaryotic and prokaryotic organisms
21. In all human cells only aerobic respiration occurs.

Table 2

Multivariate Tests of MANCOVA

Source of Variance	Wilks' Lambda	Hypothesis df	Error df	Multivariate F
PRECRCA	0.800	2	80	9.998*
Group	0.926	2	80	3.202*

PRECRCA: Pre cellular respiration concept achievement, N=84, *p<0.05

Table 3

Summary of Follow-up Univariate ANCOVAs of Dependent Variables

Source	Dependent variable	SS	df	MS	Univariate F	P
PRECRCA	POSTCRCA	156.067	1	156.067	17.446	0.000*
	ATB	20.385	1	20.385	0.183	0.670
Group	POSTCRCA	57.813	1	57.813	6.463	0.013*
	ATB	81.504	1	81.504	0.731	0.395
Error	POSTCRCA	724.603	81	8.946		
Error	ATB	9022.868	81	111.393		
Total	POSTCRCA	880.670	83			
Total	ATB	9043.253	83			

PRECRCA: Pre-cellular respiration concept achievement.

POSTCRCA: Post-cellular respiration concept achievement. N:84.

Table 4

Adjusted Means of Dependent Variables Among Groups

Dependent Variable	Group	Adjusted means
POSTCRCA	Experimental	19.057
	Control	17.380
ATB	Experiment	53.495
	Control	51.505

POSTCRCA: Post-cellular respiration concept achievement, ATB: Attitude Toward Biology, N= 84.

Which one of the following explanations is true for energy produced at the end of respiration reactions?

a. Energy produced in one cell can be utilized for the activities of other cells.

b. Heat released during the respiration is used in cellular activities.

c. Same amount of ATP is produced in both eukaryotic and prokaryotic organisms at the end of aerobic respiration reactions.

d. During glycolysis reaction 2 ATP is produced in both aerobic and anaerobic respiration reactions.

Figure 1 Example question measuring students' misconception in cellular respiration in CRCT

What kinds of reactants are used as an energy source during aerobic respiration reactions?

Many of us may have the misconception that glucose is the only one energy source during aerobic respiration reactions. If this was true, then, what is the use of eating proteins and fats? This misconception may arise due to the extensive demonstration of glucose as a reactant in the textbooks rather than other energy sources. Besides to the glucose (carbohydrate) proteins and lipids are also used in aerobic respiration reactions as an energy source. During respiration reactions carbohydrates are primary source of energy. When the organism has sufficient carbohydrate it uses first carbohydrates in the cell respiration reactions to supply its energy need.. However, during starvation or fasting, or when there is insufficient carbohydrate for energy needs, the organism uses lipids. When lipids and carbohydrates are not available, the organism uses its protein as energy source. Whatever the energy source is, carbohydrates, lipids and proteins enter glucose reducing reaction. For example, carbohydrates are converted to monasacharides and then enter into glucose reduction chain. Glucose is converted into pyruvate and then acetyl COA in order to enter Krebs Cycle. On the other hand, proteins are broken down into aminoacid fragments one segment of which loses its amino group and is converted to acetyl CoA. They can either be oxidized in the Krebs Cycle or converted into fat. The other segment of aminoacids is converted into pyruvate which is converted into glucose or acetyl CoA. The possible pathways are presented below.

Proteins -----> Amino Acids -------> Krebs Cycle

Proteins -----> Amino Acids -------> Pyruvate -------> Krebs Cycle

Proteins -----> Amino Acids -----> Pyruvate ------->Glucose ------> Glycolysis

Figure 2 Example for Conceptual Change Texts (CCT)

Figure 2 (continued)

Lipids can also serve as an energy source. They are broken down to fatty acids and glycerol. While fatty acids are changed to acetyl COA in order to enter glucose reduction reaction, glycerol is converted to glucose in order to enter respiration reaction through glycolysis pathway. The pathways can be seen below.

Lipids -------> Glycerol ------> Glycolysis

Lipids -------> Fatty Acids -----> AcetylCOA----> Krebs Cycle

As can be seen glucose is not the only reactant used in cellular respiration reactions. Other molecules, such as proteins and lipids, can also be used as energy source by organisms. Have you ever thought why people do exercise to lose weight? If the only reactant used in respiration reactions were the glucose molecule, why would people do exercise to get rid of their fats?

Figure 2 Example for Conceptual Change Texts (CCT)

Effectiveness of Conceptual Change Text Oriented Instruction on Students' Understanding of Cellular Respiration Concepts

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Abstract

The purpose of the study is to compare the effectiveness of conceptual change text oriented instruction and traditional instruction on students' understanding of cellular respiration concepts and their attitudes toward biology as a school subject. The sample of this study consisted of 84 eleventh grade students from the four classes of a high school. Two of the classes were randomly assigned to control group in which students were instructed by traditionally designed biology instruction and the other two classes were randomly assigned to experimental group in which conceptual change texts oriented instruction was implemented. Analysis of the data indicated that students exposed to conceptual change texts oriented instruction had better understanding of cellular respiration concepts than those exposed to traditional instruction. On the other hand, both experimental and control group students had similar attitudes toward biology as a school subject.

Introduction

In recent years, many of the researchers in science education have focused on students' conceptual development and cognitive processes (Mintzes, Trowbridge, Arnaudin & Wandersee, 1991; Songer, 1993; McComas, 1997; Dekkers & Thijs, 1998; Kwon & Lawson, 2000). They mainly accepted that each student has a different cognitive structure due to their different abilities, backgrounds, attitudes and experiences. According to Piaget (1969), students construct new knowledge on their previous cognitive structures. Therefore, students may generate different meanings from the upcoming information due to their different cognitive structures. Students' views and explanations of science concepts may differ from those generally accepted by the scientists. Alternative views have been given various terms including "children science" (Gilbert, Osborne & Fensham, 1982; Osborne, Bell, & Gilbert, 1983), "alternative frameworks", (Driver & Easly, 1978; Driver & Ericson, 1983), "naive beliefs" (Caramazza, McCloskey & Green, 1981), "preconceptions", (Anderson & Smith, 1987) and "misconceptions" (Cho, Kahle & Nordland, 1985; Griffiths & Preston, 1992).

Misconceptions regarding science concepts have been studied by science educators for many years (Driver, 1981, 1983; Posner, Strike, Hewson & Gertzog,

1982; Anderson & Smith 1987; Hewson & Hewson, 1983; McComas, 1997; Dekkers & Thijs, 1998; Kwon & Lawson, 2000). Studies, specifically, in biology education showed that students have misconceptions about many biological concepts (Hazel & Prosser, 1994: Westbrook & Marek, 1991; Browning & Lehman, 1988; Fisher, 1985; Brumby, 1984; Teixeria, 2000; Arnaudin & Mintzes, 1985; Yip 1998). Some of the studies in biological education have focused on the understanding of cellular respiration (Anderson, Sheldon & Dubay, 1990; Songer & Mintzes, 1994; Simpson & Marek, 1998; Haslam & Treagust, 1987; Seymour & Langden, 1991; Lawson, 1988; Fisher & Lipson, 1986). These studies demonstrated that students have several misconceptions regarding cellular respiration.

Songer and Mintzes' (1994) study conducted with 200 novice and experienced students indicated that students have difficulties in understanding the role of oxygen in cellular respiration. Students believed that O_2 is used in all steps of glucose reduction reactions. One significant misconception of novice students reported in this study was the belief that glucose is the only substrate used in the cellular respiration. Another misconception identified was the notion that CO_2 is used instead of O_2 in fermentation reactions. Students participated in this study were not able to recognize yeast as a living organism and they believed that yeast releases O_2 in the fermentation process. Another prevalent misconception was the idea that plants do not respire (Songer & Mintzes, 1994).

In addition to these, the results of the some studies concerning students' misconceptions about cellular respiration showed that students have conceptual difficulties in understanding the function of respiration. Students defined respiration as inhaling O_2 and exhaling CO_2 (Songer & Mintzes, 1994; Anderson, Sheldon, Dubay, 1990). Sanders (1993) identified same misconception in biology teachers.

Moreover, some teachers believed that respiration of plants occurs only at night. Many teachers responded that photosynthesis is the process that makes energy available for metabolism in plant. Another misconception identified in Sanders' (1993) study was that oxygen is essential for all organisms.

Yuruk and Cakır (2000) identified several misconceptions concerning cellular respiration. Some of the common misconceptions documented in this study were: heat produced during respiration reactions is used in cellular activities; glucose is a product of cellular respiration reactions; CO_2 is produced at the end of both lactic acid and alcoholic fermentation reactions; yeast makes photosynthesis instead of respiration under light; all the energy released during cellular respiration reactions is stored; glycolysis in fermentation reactions requires more energy than that in aerobic respiration reactions. The other misconceptions identified in this study were the notions that only aerobic respiration occurs in muscle cells and water is produced as a result of fermentation reactions.

Since new knowledge is constructed on the base of existing cognitive structure, misconceptions have to be dispelled in order to prevent new ones developing. However, students' misconceptions may be so resistant to change that traditional instruction may be inadequate to change those with scientific concepts (Anderson & Smith, 1987; Champagne, Gunstone & Klopfer, 1985; Driver & Easly, 1978; Fredette & Lochead, 1980; Osborne, 1983; Wandersee et al, 1994). Recent studies in science education have showed that teaching strategies based on conceptual change approach have been effective at dispelling students' misconceptions. Posner et al. (1982) postulated four conditions that are necessary for conceptual change to occur: (a) there must be dissatisfaction with the existing conception (that is, prior concept must be inadequate to solve existing problem), (b) the new conception must

be intelligible (that is, conception must be understandable), (c) the new conception must appear initially plausible (that is, it must be useful in solving the problems), (d) the new conception must be fruitful (that is, it must be useful in solving future problems).

One of the successful techniques based on conceptual change approach is the use of conceptual change texts which refute commonly held naive concepts (Dole & Niedehauser, 1990; Hynd & Alverman, 1986; Maria & MacGinitie, 1987; Chambers & Andre, 1997; Guzetti, Synder, Glass, & Gamas, 1993). The aim of using conceptual change text is to activate learners' preconceptions and warn learners about possible misconceptions about the topic of interest. In conceptual change texts misconceptions are contrasted with the scientifically accepted conceptions by providing examples and explanations. In these texts learners are asked explicitly to make prediction about a given situation before presenting the misconceptions and explanations about the given situation and they are recommended to change their misconceptions with scientifically accepted ones (Chambers & Andre, 1997).

Cellular respiration has a central role in understanding of several conceptual change schemes including energy flow in ecosystem and metabolic activities of organisms such as digestion, circulation, respiration and excretion. In order to understand these concepts meaningfully, and to prevent the development of new scientifically unacceptable conceptions, misconceptions about cellular respiration should be remedied. The purpose of this study is to compare the effectiveness of conceptual change texts oriented instruction and traditionally designed instruction on students' understanding of cellular respiration and their attitudes toward biology as a school subject.

Method

Subjects

Participants in this study were 84 eleventh grade students from the four classes of the same teacher in a high school. Two classrooms of experimental group with 40 students were randomly assigned to conceptual change texts oriented instruction (CCTI) while traditionally designed biology instruction (TBI) was assigned to the other two classes with 44 students.

Research Design

Pre-test post-test experimental design was used as a research design. Students in control group were taught by traditionally designed instruction while students in experimental group were exposed to conceptual change text oriented instruction. Cellular respiration concept test was administered as pre-test in order to control previous learning and existing conceptions in cellular respiration. Same test was administered as post-test to determine students' understanding of cellular respiration concepts. In addition to that, attitude scale was implemented in both experimental and control groups after the instruction

Instrumentation and Materials

Cellular Respiration Concepts Test (CRCT)

In order to assess students' understanding of cellular respiration concepts a 23 item multiple choice concept test was developed by the researchers. During the development of Cellular Respiration Concepts Test (CRCT), firstly, instructional objectives of the unit "Cellular Respiration" were stated. Secondly, students' typical conceptual difficulties, and misconceptions were identified from

previous studies in literature and from the informal interviews with 3 biology teachers who have more than 5 years of experience in teaching biology. The misconceptions identified through literature review and those identified as a result of informal interviews with the teachers are presented in Table 1. Finally, items of the test were constructed according to the instructional objectives and identified misconceptions about cellular respiration concepts. Each item of the test had one correct answer and three distracters which reflected students' misconceptions related to cellular respiration. One of the items in CRCT is shown in Figure 1. In distracter A of this item, it was aimed to examine students' understanding of energy production at the end of respiration reactions. Students who have this misconception may think that energy produced in one cell may be used by other cells. The students who hold the misconception that heat produced during the respiration reaction may be used in cellular activities may select the distracter B. If they are unable to identify the difference between eukaryote and prokaryote organism's energy production in respiration reactions, they may choose distracter C. Some students may also not understand that the same amount of energy produced in glycolysis reaction occurs in both aerobic and anaerobic respiration reactions. Therefore, they may be unable to find answer D.

A group of experts in measurement and evaluation, biology, and biology education examined this test for representativeness and appropriateness of the test items. The pilot study of the test was implemented to 193 eight and ninth grade students in a high school. The reliability of the test was found to be .80. Final form of the test was administered as a pre-test and post-test to both control and experimental groups.

Attitude Scale Toward Biology As A School Subject (ATB)

In order to measure students' attitudes toward biology as school subject the scale developed by Geban et al. (1994) was used. Geban et al. (1994) developed an attitude scale toward chemistry. This scale was adapted so that it measures students' attitudes toward biology as a school subject. The scale contains 15 Likert type items regarding enjoyment and importance of biology course. The reliability of the scale was found to be 0.89.

Conceptual Change Texts

The conceptual change texts (CCT) used in this study was designed to help students change their preconceptions or misconceptions with the scientific ones. Conceptual change texts were developed incorporating the four conditions of conceptual change approach (Posner et al., 1982). Firstly, students were asked a question about a given situation in order to activate their prior knowledge. Then, students were informed about common misconceptions regarding the topic. Next, scientific explanations and examples were provided about the topic to refute the common misconceptions. It was emphasized that the misconceptions fail to explain the real phenomena. Finally, students were asked further questions in order to stimulate them to apply the new concept to answer the question. An example to the conceptual change texts can be seen in Figure 2.

Procedure

This study took place over four weeks. Before the treatment, the teacher was trained about the data collection procedure and implementation of CCT. After training the teacher, cellular respiration concept test was administered in both experimental

and control groups as pre-test. One week after the administration of pre-test instruction concerning cellular respiration was started in both groups. In the traditionally designed biology instruction, the teacher provided instruction through lecture and discussion. Meanwhile, experimental group was instructed by using conceptual change texts. The teacher, firstly, explained the concepts though lecturing and, then, used conceptual change texts to supplement his instruction.

During the implementation of CCT, students were asked to read the CCT before coming to school. In the classroom the teacher posed the questions in the text to activate students' preconceptions. Students were directed to answer the questions by themselves. Then, the scientific explanation of the concept was read from CCT by emphasizing that common misconceptions do not explain the real phenomena. Students were asked to discuss whether their responses to questions were scientifically acceptable or not. Finally, students were advised to replace their existing concepts with the scientific ones. One week after the treatment, CRCT and ATB were administered to both experimental and control groups as post tests.

Results

In order to compare the effectiveness of conceptual change texts oriented instruction (CCTI) and traditionally designed biology instruction (TBI) with respect to students' understanding of cellular respiration concepts and their attitudes toward biology as a school subject Multivariate Analysis of Covariance (MANCOVA) was used. The dependent variables were students' attitudes toward biology (ATB) and their cellular respiration concept achievement (CRCA) measured by post-CRCT scores. The independent variables were treatment called as group and students' pre-cellular respiration concept achievement (pre-CRCA) measured by pre-CRCT scores.

In order to statistically equalize differences between experimental and control groups, students' pre-cellular respiration concept achievement was determined as a potential covariate in the MANCOVA. The covariate, pre-CRCA, was entered before the group into the model so that the variance caused by pre-achievement can be removed from the variance caused by group on the dependent variables. Table 2 summarizes the result of the multivariate tests of MANCOVA.

As table 2 indicates, group resulted in significant multivariate F. This means that there was found a significant mean difference between students taught with conceptual change oriented instruction and those exposed to TBI with respect to the collective dependent variables of students' understanding of cellular respiration concepts and their attitudes toward biology as a school subject.

In order to decide which dependent variable was responsible for the significance the results of follow-up ANCOVAs are examined. Table 3 presents the results of follow-up ANCOVAs. Table 3 shows that the group resulted in a significant univariate F for post-cellular respiration achievement although it did not result in significant univariate F for attitude toward biology. That is there was a significant mean difference between experimental and control group students in terms of their cellular respiration concepts understanding. However, the results indicate that there was no significant difference between experimental and control groups in terms of their attitudes toward biology. The direction of the effect of the treatment can be examined through the adjusted means for each dependent variable among groups. Table 4 demonstrates the adjusted means for the dependent variables across groups. As table 4 indicates, experimental group has higher adjusted mean value of post-cellular respiration achievement.

Discussion and Implication

The main aim of the study was to compare the effectiveness of conceptual change text oriented instruction and traditionally designed biology instruction with respect to students understanding of cellular respiration concepts and their attitudes toward biology as a school subject. The results show that there is a significant difference between CCTI and TBI with respect to students' understanding cellular respiration. Students who were exposed to CCT had better understanding of cellular respiration concepts than those who were taught by traditional instruction. This finding of the study is supported by the previous studies (Wang & Andre, 1991; Guzzetti et al., 1993, Hynd et al., 1994). The difference in understanding cellular respiration concept between students exposed to CCTI and those exposed to TBI can be attributed to the nature of conceptual change texts.

In this study conceptual change text oriented instruction helped students have better understanding of cellular respiration concepts by activating their misconceptions, producing dissatisfaction and providing correct explanation which is both understandable and plausible. Moreover, text-based materials encouraged intensive student-student, student- teacher interaction during discussion section to understand concepts accurately. On the other hand, during the TBI students' preconceptions and misconceptions were ignored during instruction. Thus, students in TBI group acquired scientific conceptions with the continued presence of the alternative conception in their conceptual framework..

Although CCTI had significant effects on students' understanding of cellular respiration concepts, it did not make a significant difference in students' ATB as a school subject. Both groups showed statistically the similar attitudes toward biology. Textual information is one of the primary learning activities in school settings. Use of

text-based information is not a significant change for the students. Therefore, these texts may have not created difference in students' ATB as a school subject. At least the result of this study show that conceptual change texts did not produce negative attitudes toward biology.

Previous studies have shown that students have various misconceptions about several science topics. If these misconceptions are ignored during instruction, new misconceptions can be developed in students' minds which may hinder meaningful understanding of science concepts. This study shows that conceptual change texts can be used as an effective tool to prevent or change students' misconceptions. Therefore, teachers should be informed about conceptual change text oriented instruction in order to promote conceptual change in students' cognitive structures. Moreover, conceptual change texts can be incorporated into textbooks. Through the use of conceptual change texts money and effort can be saved compared to the other learning activities in which extra instructional materials are used.

References

Anderson, C.W., Sheldon, T. H., & Dubay, J. (1990). The effects of instruction on college nonmajors conceptions of respiration and photosynthesis. *Journal of Research in Science Teaching, 27* (8), 761-776.

Anderson, C. W., & Smith, E. L. (1987). Teaching science. In V. Richardson-Koehler (Ed.), *Educator's handbook: A research prospective* (pp.84-111). New York: Longman.

Arnaudin, M. W., & Mintzes, J. J. (1985). Students' alternative conceptions of the human circulatory system: A cross age study. *Science Education, 69*(5), 721-733.

Browning, M.E., & Lehman, J. D. (1988). Identification of student misconceptions in genetics problem solving via computer program. *Journal of Research in Science Teaching 25*(9), 747-761.

Brumby, M.N. (1984). Misconceptions about the concept of natural selection by medical biology students. *Science Education ,68*(4) 493-503.

Yuruk, N., & Cakir, O. S. (2000). Lise ogrencilerinde oksijenli ve oksijensiz solunum konusunda gorulen kavram yanılgılarının teshisi. [Diagnosing high school students' misconceptions about aerobic and anaerobic respiration] *Hacettepe Universitesi Egitim Fakultesi Dergisi. 18*, 185-191.

Caramazza, A., McCloskey, J., & Green, B. (1981). Naive beliefs in sophisticated subjects: Misconceptions about trajectories of objects. *Cognition*, 9, 111-123.

Chambers, K. S., & Andre, T. (1997). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current. *Journal of Research in Science Teaching, 34*, 107-123.

Champagne, A., Gunstone, R., & Klopfer, L. (1985). Effecting changes in cognitive structures among physical students. In L. West and L. Pines (Eds.), *Cognitive Structure and Conceptual Change*. London: Academic Press.

Cho, H., Kahle, J. B., & Nordland, F. H. (1985). An investigation of high school textbooks as source of misconceptions and difficulties in genetics and some suggestions for teaching genetics. *Science Education, 69*, 707-719.

Dekkers, P.J.J.M. & Thijs, G.D. (1998). Making productive use of students' initial conceptions in developing the concept of force. *Journal of Research in Science Teaching*, 31-50.

Dole, J. A., & Niederhauser, D. S. (1990). Student's level of commitment to their naive conceptions and their conceptual change learning from texts. In J. Zutell and McCormick (Eds.), *Literacy theory and research: Analyses from multiple paradigms.* Chicago: National Reading Conference.

Driver, R., & Easly, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education, 5*, 61-84.

Driver, R. (1981). Pupils' alternative frameworks in science. *European Journal of Science Education, 3*(1), 93-101.

Driver, R. (1983). *The pupil as scientist.* Milton Keynes, England: The Open University Press.

Driver, R. & Erickson, G. (1983). Theories in action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science. *Studies in Science Education, 10*, 37-60.

Fisher, K. M. (1985). A misconception in biology: Amino acids and translation. *Journal of Research in Science Teaching, 22*(1), 53-62.

Fisher, K. M. & Lipson, J. I. (1986). Twenty misconceptions about students' errors *Journal of Research in Science Teaching, 23* (9), 783-803.

Fredette, N.H., & Lockhead, J.(1980). Student conceptions of simple circuits. *The Physics Teacher, 18* (3), 194-198

Geban, Ö., Ertepınar, H., Yılmaz, G., Altın, A., & Şahbaz, F. (1994). Bilgisayar destekli eğitimin öğrencilerin fen başarılarına ve fen bilgisi ilgilerine etkisi [The effect of computer adapted instruction of students' science achivement and on their attitudes toward science]. *I. Ulusal Fen Bilimleri Eğitimi Sempozyumu Bildiri Özetleri Kitabı* (pp.1-2). 9 Eylül University, İzmir.

Gilbert, J. K., Osborne, R. J., & Fensham, P. J. (1982). Children's science and its consequences for teaching. *Science Education, 66*, 623-633.

Griffiths, A. K., & Preston, K. R. (1992). Grade-12 students' misconceptions relating to fundamental characteristics of atoms and molecules. *Journal of Research in Science Teaching, 29*, 611-628.

Guzzetti, B. J., Snyder, T. E., Glass, G.V., and Gamas, W. S. (1993). Meta analysis of instructional interventions from reading education and science education to overcome misconceptions. *Reading Research Quarterly, 28*, 116-159.

Haslam, F., & Treagust, D. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of Biological Education, 21*, 203-211.

Hazel, E. & Prosser, M. (1994). First-year university students' understanding of photosynthesis, their study strategies and learning context. *American Biology Taecher, 56(*5), 274-279.

Hewson, G. M., & Hewson, W. P. (1983). Effect of instruction using students' prior knowledge and conceptual change strategies on science learning. *Journal of Research in Science Teaching, 20*, 731-743.

Hynd, C., & Alverman, D.E. (1986). The role of refutation text in overcoming difficulty with science concepts. *Journal of Reading, 29*, 440-446.

Hynd, C.R., McWhorter, J.Y., Phares, U.L., & Suttless, C.W. (1994). The role of instructional variables in conceptual change in high school physics topics. *Journal of Research in Science Teaching, 31* (9), 933-946.

Kwon, Y., & Lawson, A.E. (2000). Linking brain growth with the development of scientific reasoning ability and conceptual change during adolescence. *Journal of Research in Science Teaching, 37* (1), 44-62.

Lawson, A.E. (1988) The acquisition of biological knowledge during childhood: Cognitive conflict or Tabula Rasa. *Journal of Research in Science Teaching. 25*(3), 185-199.

Maria, K., & MacGinitie, W. (1987). Learning from texts that refute the reader's prior knowledge. *Reading Research and Instruction, 26*, 222-238.

McComas, W.F. (1997). The discovery and nature of evolution by natural selection: Misconceptions and lessons from the history of science. *The American Biology Teacher, 59*(8), 492-500.

Mintzes, J.J. (1984). Naïve theories in biology: children's concepts of the human body. *School Science and Mathematics. 84*(7), 548-555.

Mintzes, J., Trowbridge, J., Arnaudin, M., & Wandersee, J. (1991). Children's biology: Studies on conceptual development in the life sciences. In S. Glynn, R. Yeany, & B. Britton (Eds.), *The psychology of learning science* (pp. 179-202). Hillsdale, N.J.: Erlbaum.

Osborne, R.J., (1983). Towards modifying children's ideas about electric current. *Research in Science and Technological Education, 1*, 73-82.

Osborne, R. J., Bell, B. F., & Gilbert, Y. K. (1983). Science teaching and children's view of the world. *European Journal of Science Education, 5*, 1-14.

Piaget, J. (1969). *The child's conception of the world.* Totowo, NJ: Littlefield, Adams, & Co.

Posner, G.J., Strike, K.A., Hewson, P.W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*, 211-227.

Sanders, M. (1993) Erroneous ideas about respiration: The teacher factor. *Journal of Research in Science Teaching, 30(8), 919-934.*

Seymour, J., & Longden, B. (1991). Respiration-That's breathing isn't it? *Journal of Biological Education, 25*, 177-183.

Simpson, W.D., & Marek, E.A. (1988). Understandings and misconceptions of biology concepts held by students attending small high schools and students attending large high schools. *Journal of Research in Science Teaching, 25*, 361-374.

Songer, C. (1993). *Understanding cellular respiration.* Unpublished master's thesis, University of North Carolina at Wilmington, Wilmington, NC.

Songer, C.J.& Mintzes, J.J (1994). Understanding cellular respiration and analysis of conceptual change in college biology. *Journal of Research in Science Teaching. 31* (6), 621-637.

Teixeira, F. (2000). What happens to the food we eat? Children's conceptions of the structure and function of the digestive system. *International Journal of Science Education. 22*(5), 507-520.

Wandersee, J., Mintzes, J., & Novak, J.D. (1994). Research on alternative conceptions in science. In D. Gabel (Ed.) *Handbook of research on science teaching and learning* (pp. 177-210). New York: Macmillan.

Wang, T. & Andre, T. (1991). Conceptual change text and application questions versus no questions in learning about electricity. *Contemporary Educational Psychology, 16*, 103-116.

Westbrook, S. L., & Marek, E. A. (1991). A cross-age study of student understanding of the concept of diffusion. *Journal of Research in Science Teaching, 28*(8), 649-660.

Table 1

Students' Misconceptions Concerning Cellular Respiration.

1. Plants do not respire.
2. Plants respire only at night.
3. O_2 is directly used during glucose reduction reactions.
4. O_2 is used during anaerobic respiration reactions.
5. While animals produce CO_2, plants produce O_2 at the end of respiration
6. All living things use O_2 during respiration reaction.
7. During anaerobic respiration reaction CO_2 is used instead of O_2
8. Inhaling oxygen and exhaling CO_2 is called respiration.
9. CO_2 is produced during both aerobic and anaerobic respiration reactions.
10. CO_2 is produced during both lactic acid and alcoholic fermentation reactions.
11. Energy is produced at the end of photosynthesis reactions
12. Energy produced in one cell is used in other cellular activities.
13. Heat produced during respiration is used in cellular activities.
14. Glucose is produced as a result of respiration.
15. Glucose is used in all respiration reaction.
16. Only yeast makes anaerobic respiration reactions.
17. Yeast makes photosynthesis under light.
18. During glycolysis in fermentation reaction more O_2 is required as compared to aerobic respiration reaction.
19. All energy produced during respiration is stored.
20. Same amount of ATP is produced for both eukaryotic and prokaryotic organisms
21. In all human cells only aerobic respiration occurs.

Table 2

Multivariate Tests of MANCOVA

Source of Variance	Wilks' Lambda	Hypothesis df	Error df	Multivariate F
PRECRCA	0.800	2	80	9.998*
Group	0.926	2	80	3.202*

PRECRCA: Pre cellular respiration concept achievement, N=84, *p<0.05

Table 3

Summary of Follow-up Univariate ANCOVAs of Dependent Variables

Source	Dependent variable	SS	df	MS	Univariate F	P
PRECRCA	POSTCRCA	156.067	1	156.067	17.446	0.000*
	ATB	20.385	1	20.385	0.183	0.670
Group	POSTCRCA	57.813	1	57.813	6.463	0.013*
	ATB	81.504	1	81.504	0.731	0.395
Error	POSTCRCA	724.603	81	8.946		
Error	ATB	9022.868	81	111.393		
Total	POSTCRCA	880.670	83			
Total	ATB	9043.253	83			

PRECRCA: Pre-cellular respiration concept achievement.

POSTCRCA: Post-cellular respiration concept achievement, N:84,

Table 4

Adjusted Means of Dependent Variables Among Groups

Dependent Variable	Group	Adjusted means
POSTCRCA	Experimental	19.057
	Control	17.380
ATB	Experiment	53.495
	Control	51.505

POSTCRCA: Post-cellular respiration concept achievement, ATB: Attitude Toward Biology, N= 84.

Which one of the following explanations is true for energy produced at the end of respiration reactions?

a. Energy produced in one cell can be utilized for the activities of other cells.

b. Heat released during the respiration is used in cellular activities.

c. Same amount of ATP is produced in both eukaryotic and prokaryotic organisms at the end of aerobic respiration reactions.

d. During glycolysis reaction 2 ATP is produced in both aerobic and anaerobic respiration reactions.

Figure 1 Example question measuring students' misconception in cellular respiration in CRCT

What kinds of reactants are used as an energy source during aerobic respiration reactions?

Many of us may have the misconception that glucose is the only one energy source during aerobic respiration reactions. If this was true, then, what is the use of eating proteins and fats? This misconception may arise due to the extensive demonstration of glucose as a reactant in the textbooks rather than other energy sources. Besides to the glucose (carbohydrate) proteins and lipids are also used in aerobic respiration reactions as an energy source. During respiration reactions carbohydrates are primary source of energy. When the organism has sufficient carbohydrate it uses first carbohydrates in the cell respiration reactions to supply its energy need.. However, during starvation or fasting, or when there is insufficient carbohydrate for energy needs, the organism uses lipids. When lipids and carbohydrates are not available, the organism uses its protein as energy source. Whatever the energy source is, carbohydrates, lipids and proteins enter glucose reducing reaction. For example, carbohydrates are converted to monasacharides and then enter into glucose reduction chain. Glucose is converted into pyruvate and then acetyl COA in order to enter Krebs Cycle. On the other hand, proteins are broken down into aminoacid fragments one segment of which loses its amino group and is converted to acetyl CoA. They can either be oxidized in the Krebs Cycle or converted into fat. The other segment of aminoacids is converted into pyruvate which is converted into glucose or acetyl CoA. The possible pathways are presented below.

Proteins -----> Amino Acids -------> Krebs Cycle

Proteins -----> Amino Acids -------> Pyruvate -------> Krebs Cycle

Proteins -----> Amino Acids -----> Pyruvate -------->Glucose ------> Glycolysis

Figure 2 Example for Conceptual Change Texts (CCT)

Figure 2 (continued)

Lipids can also serve as an energy source. They are broken down to fatty acids and glycerol. While fatty acids are changed to acetyl COA in order to enter glucose reduction reaction, glycerol is converted to glucose in order to enter respiration reaction through glycolysis pathway. The pathways can be seen below.

Lipids -------> Glycerol ------> Glycolysis

Lipids -------> Fatty Acids -----> AcetylCOA----> Krebs Cycle

As can be seen glucose is not the only reactant used in cellular respiration reactions. Other molecules, such as proteins and lipids, can also be used as energy source by organisms. Have you ever thought why people do exercise to lose weight? If the only reactant used in respiration reactions were the glucose molecule, why would people do exercise to get rid of their fats?

Figure 2 Example for Conceptual Change Texts (CCT)